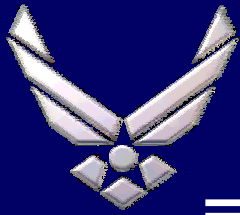


Aircraft Wiring System Integrity Initiatives

George Slenski
Materials Directorate
Air Force Research Laboratory
AFRL/MLSA
WPAFB, OH 45433
Ph 937-656-9147
email: george.slenski@wpafb.af.mil

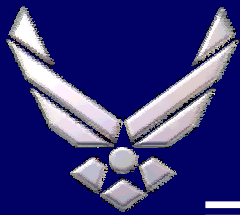




Outline



- Wiring Failure Mechanisms
- Extent of Wiring Problems
- Aging Wiring Defined
- Program Initiatives
- Summary



Wiring Failure Mechanisms



Electrical



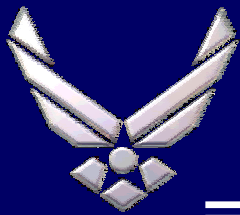
Mechanical



Thermal



Chemical

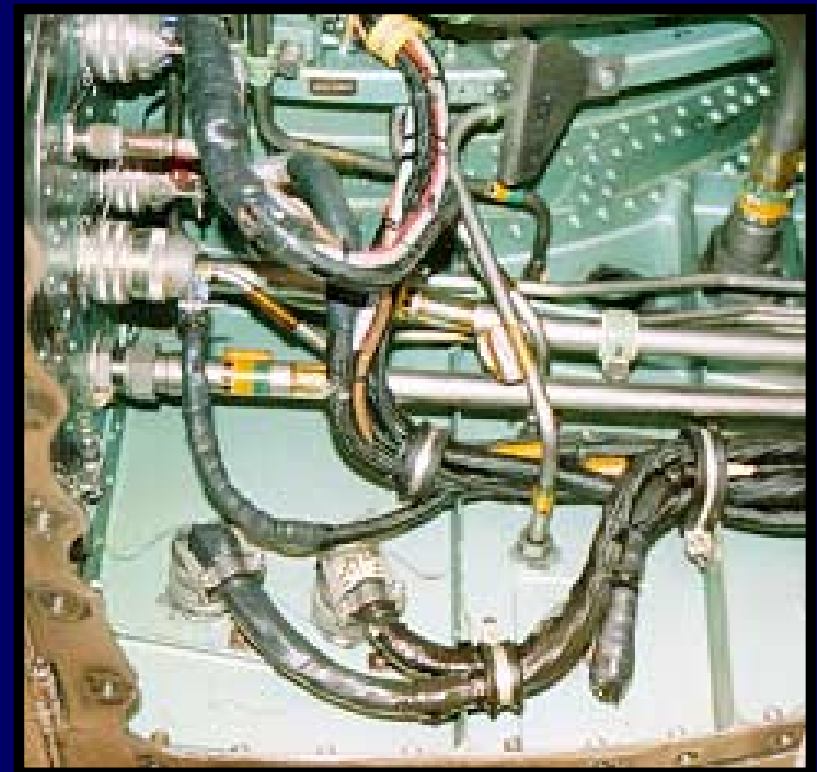


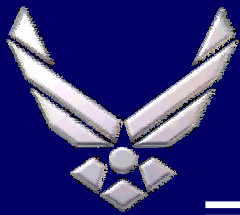
Wiring Installation



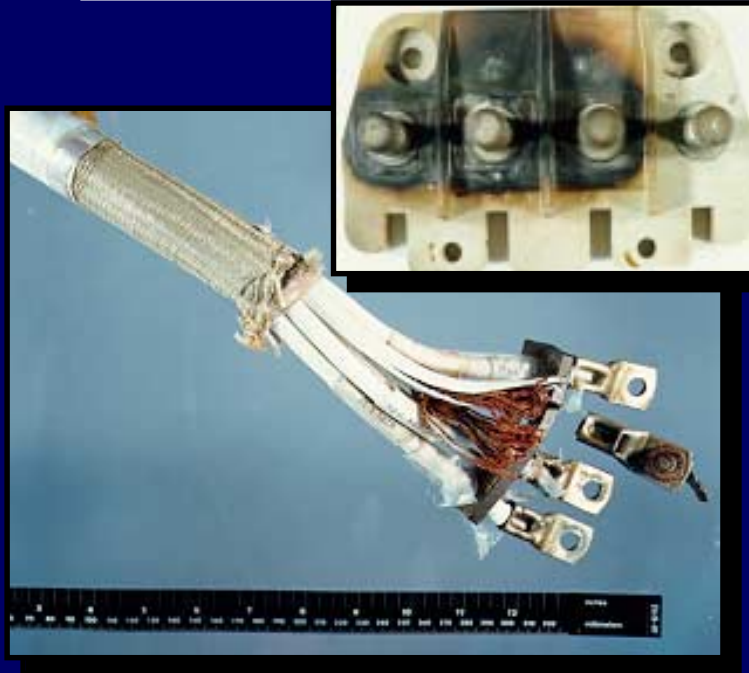
Typical Wiring Distribution
in a Fighter

Wiring Must Withstand
Continuous Environmental
Exposure





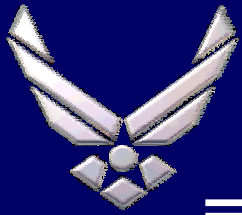
Excessive Temperature



Aircraft Generator Cable

Long Term High
Temperature
Exposure and
Excessive Power





Arc Tracking Wire Failures

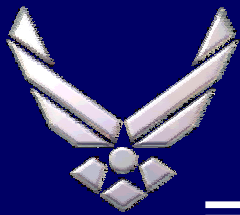
Field Failure



Dry Arc Tracking



Polyimide Insulation
(MIL-W-81381)



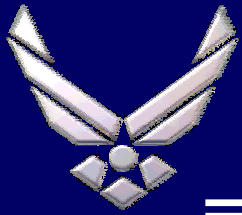
Arc Tracking Failures



Field Wet Arc
Tracking Failure
Polyalkene Insulation

Insulation Damage by Hot
Stamp Printing Process
Wiring Located in
High Moisture Environment

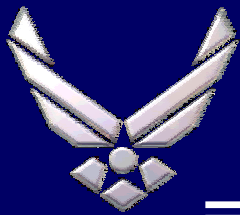




Aging Aircraft Wiring Systems



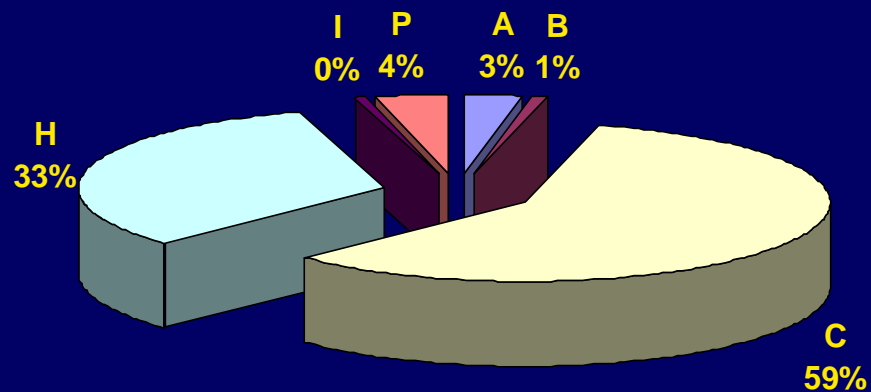
- Wiring Failure Data for a Typical Fighter
 - 46% Broken Wires
 - 30 % Insulation Chafing Damage
 - 14% Outer Layer Chafing
 - 10% Failure in Connector



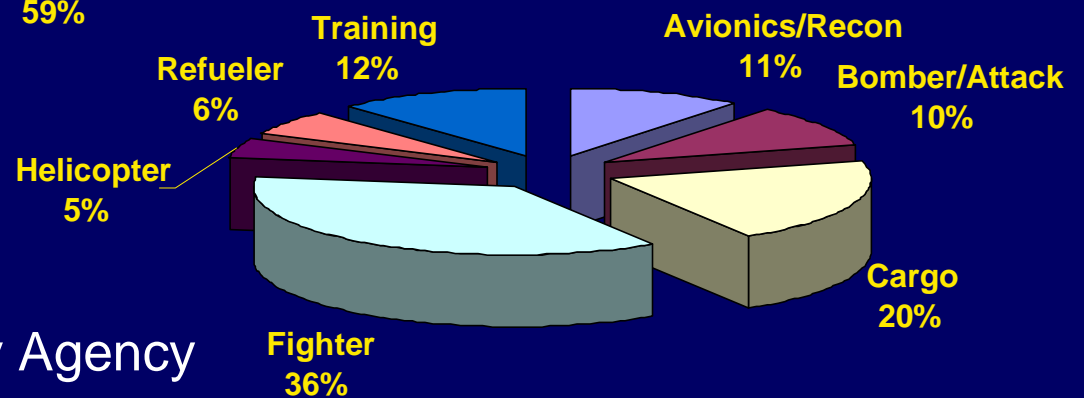
AF Mishap Data for Electronic Related Failures (1989-99)



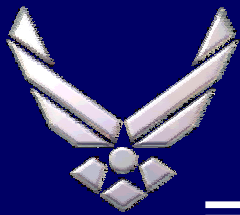
Mishap class



Aircraft Type



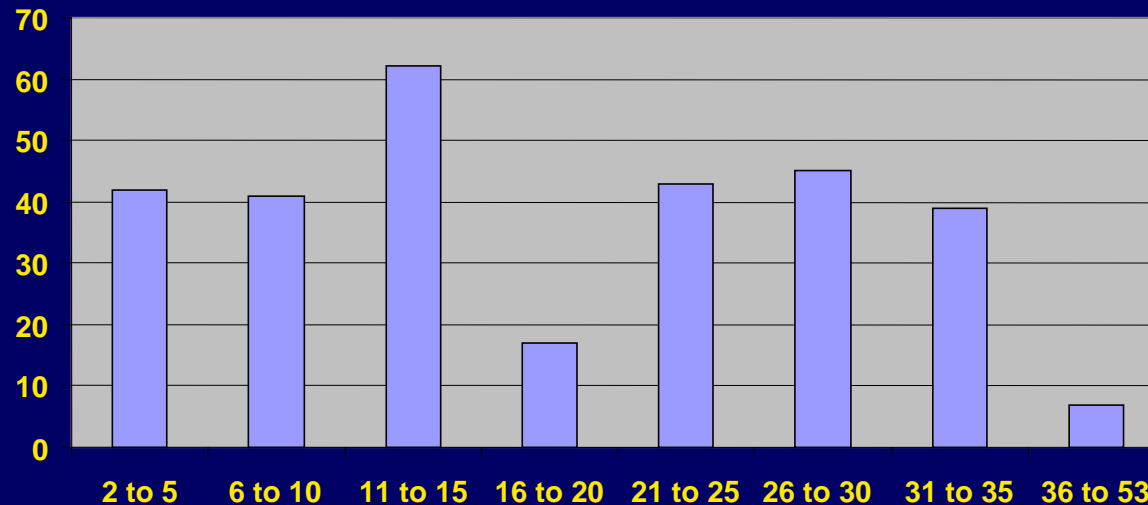
Data provided by the AF Safety Agency



AF Mishap Data for Electronic Related Failures (1989-99)

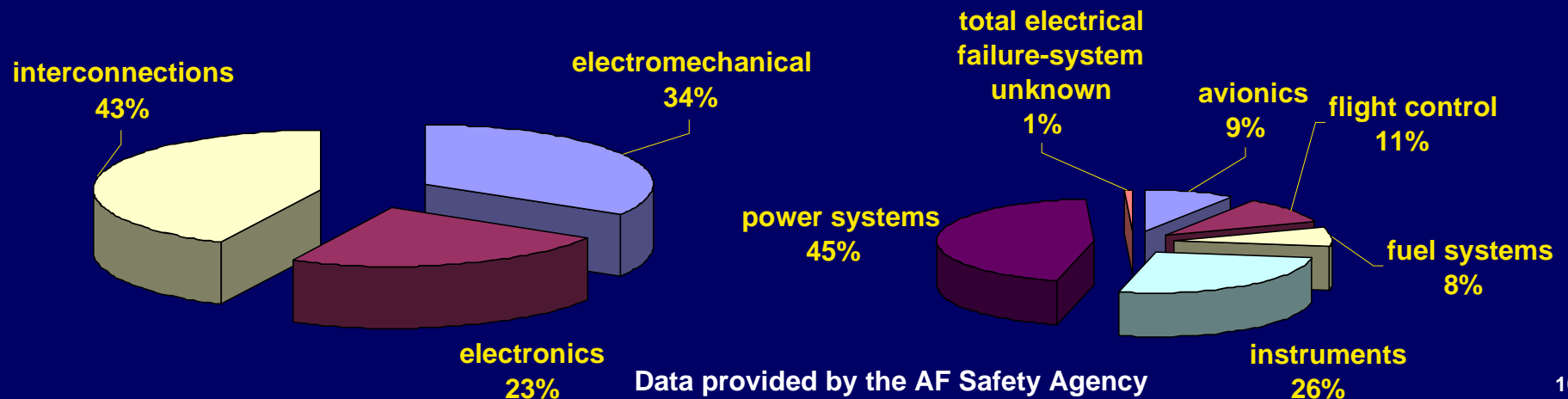


Age Groups of Mishap Aircraft

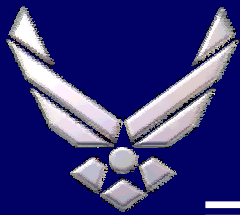


Function

System



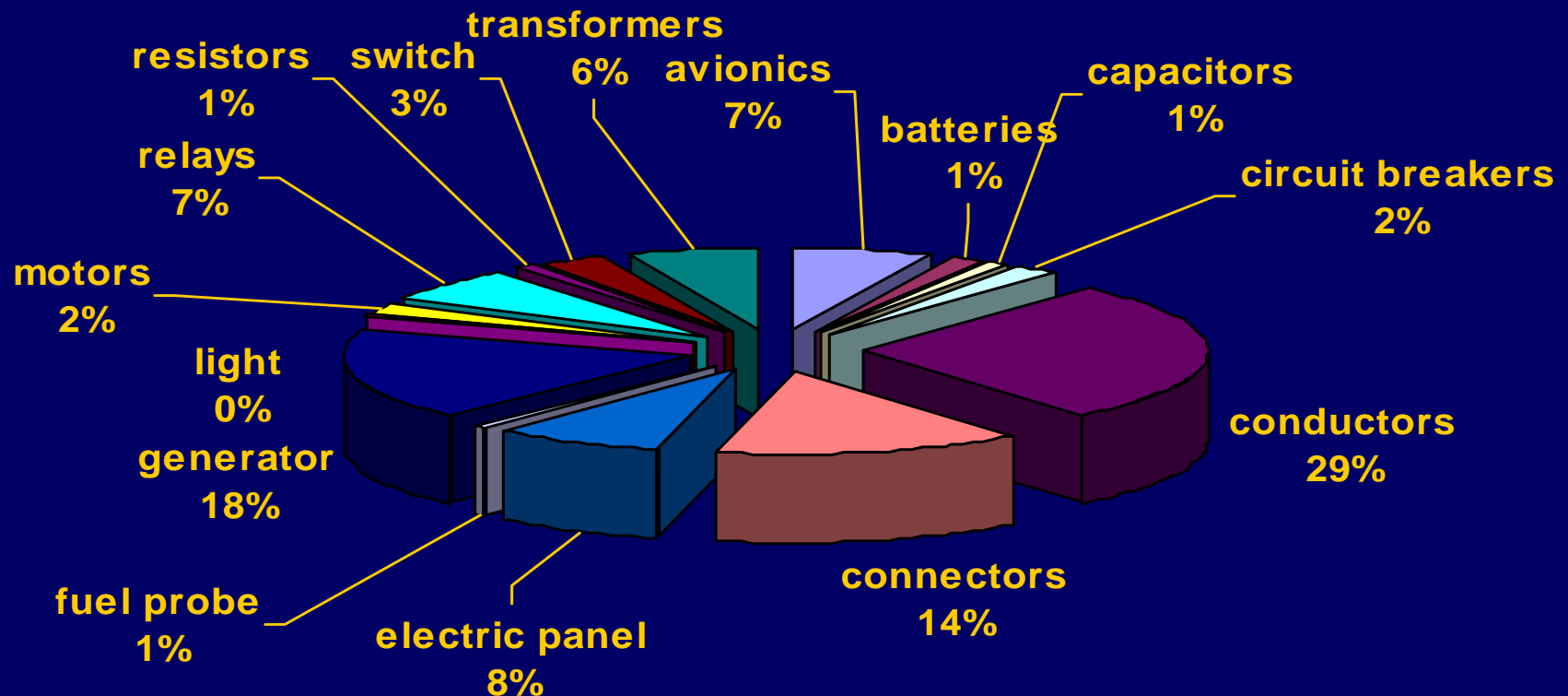
Data provided by the AF Safety Agency



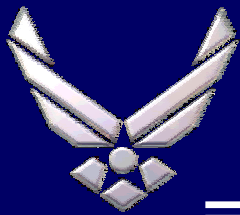
AF Mishap Data for Electronic Related Failures (1989-99)



Components Contributing to AF Mishaps



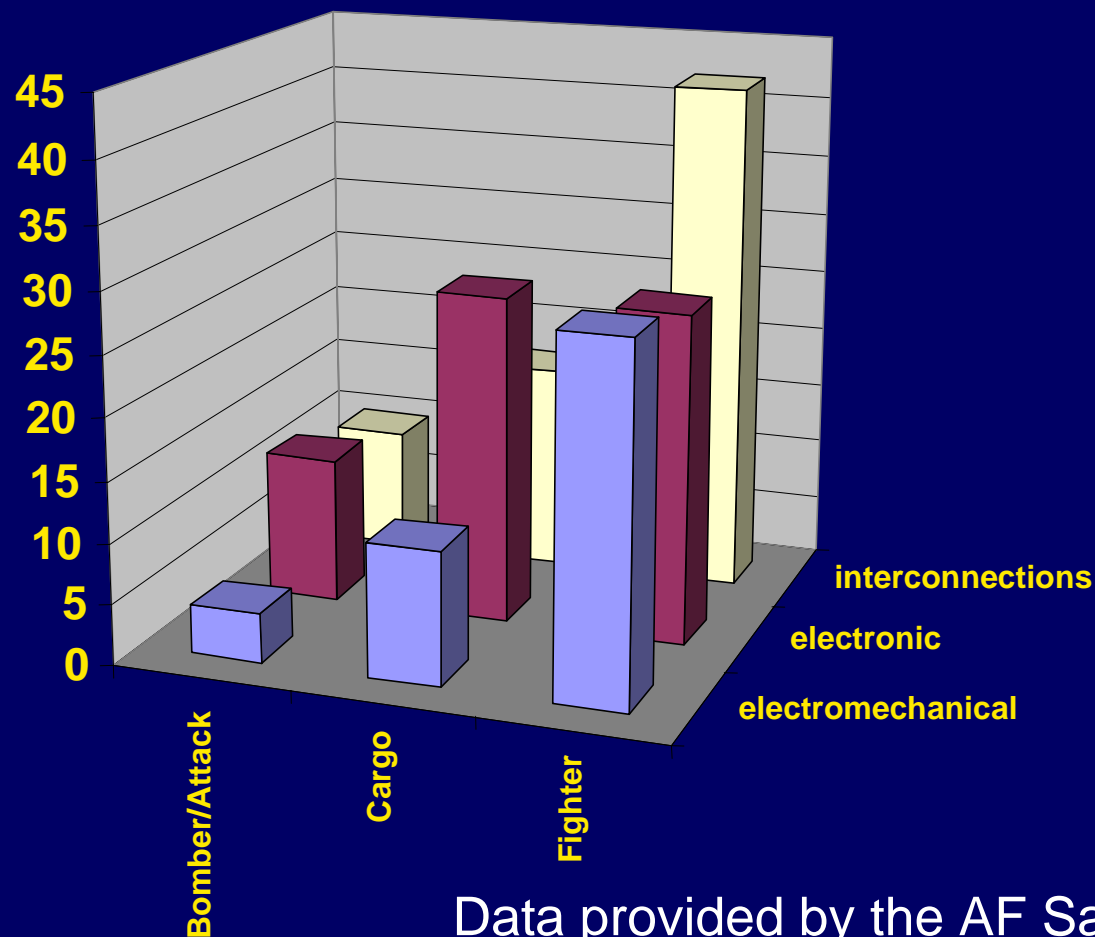
Data provided by the AF Safety Agency



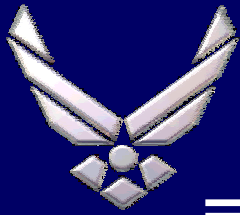
AF Mishap Data for Electronic Related Failures (1989-99)



Function of Failed Component by Aircraft Type

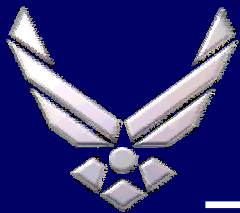


Data provided by the AF Safety Agency

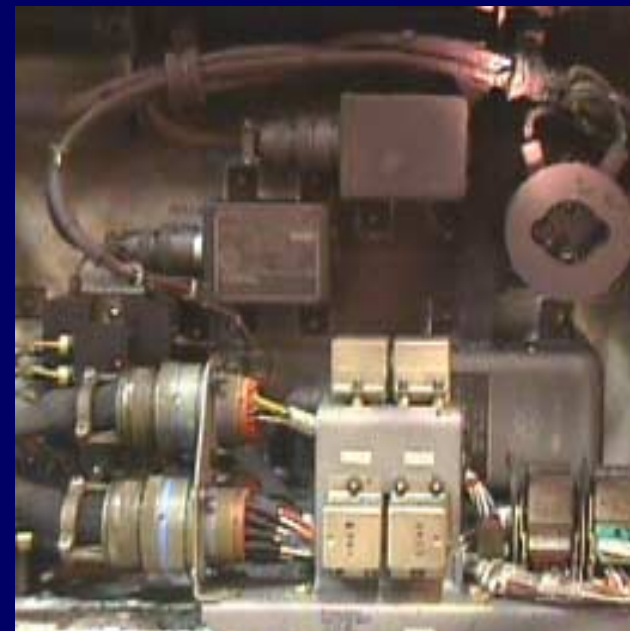
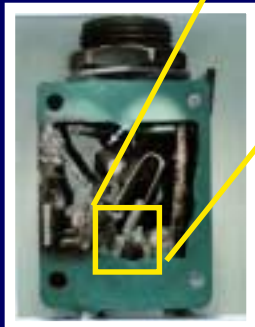


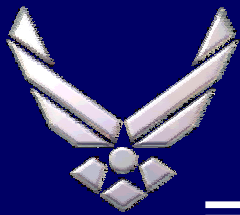
Aging Wiring Defined

- Wiring is just one part of the electrical interconnection system
 - Wiring, connectors, relays, circuit breakers, power distribution panels, and generators makeup the system
- Aging wiring can result in degraded performance due to accumulated damage from long-term exposure.
 - Damage is from chemical, thermal, electrical, and mechanical stresses
 - Stresses are often induced by the operational environment and installation and maintenance practices
 - Wiring failures often appear as broken conductors and damaged insulation which can disrupt electrical signals and/or lead to arcing.



Wiring "System"





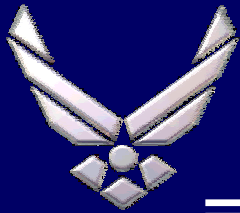
Wiring System Failures



In-Flight Electrical Fire



Initiation Site



Program Activities

Wire Integrity Study Objectives

- Identify field failure mechanisms/issues
- Review current maintenance practices
- Review current inspection technologies

Goal

- Define requirements for a wire integrity test system

Wire Integrity Tester Objectives

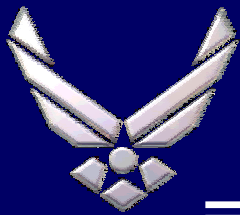
- Provide electrical characterization of wiring
- Diagnostic and predictive capability

Goal

- Deploy a field level wiring diagnostic and verification system

AF SPO Depot and field units

Navy, NASA, and FAA Support



Wiring Integrity Study of Legacy Aircraft

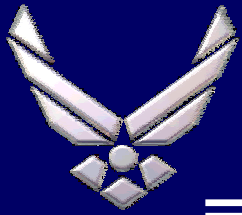


Purpose:
Define requirements
for a wire integrity test system



- Approach:
 - Inspect aircraft
 - Identify failure mechanisms/issues
 - Review current maintenance practices
 - Review current inspection technologies

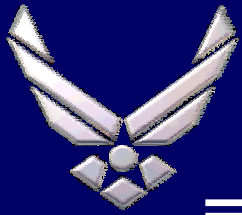
Contractor: GRCI
Funding: \$100K
Start Date: March 2000
Duration: Six months
POC: George Slenski



Wiring Integrity Study of Legacy Aircraft Results- Fighter Aircraft Wing



- Most wiring problems are found through trouble-shooting not inspection
- When one wire fault is found typically additional wire damage is present
- Hand-held multi-meters primarily used for trouble-shooting
- The problems are in exposed areas (wheel well) and those with moving parts such as the wing flaps
- Wire harnesses typically replaced when damage is found

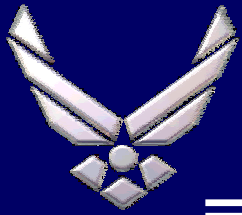


Wiring Integrity Study of Legacy Aircraft Results- Fighter Aircraft Wing



Needs

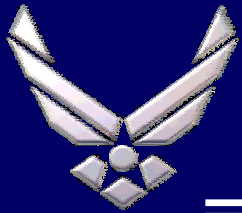
- A universal tester to replace aging testers
- Tester that is easy to use and mobile
- Less than an one hour setup time and no larger than a briefcase
- Data recording that could be used for preventative maintenance
- Identification of where a fault is physically located (SWR, TDR)
- Use of a standards/results format to show where faults are located
- Incorporation of test instructions with equipment
- Identification of sticking relays and trends in the contact resistances
- Testing of load capabilities of circuit breakers and panels



Wiring Integrity Study of Legacy Aircraft Results- Large Aircraft Wing



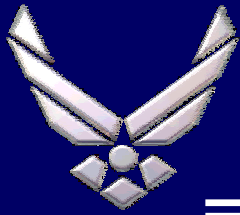
- Wing has to test aircraft in a fueled environment making safety a major concern
- Many wires pass in a “no load” condition yet fail in “load” condition
 - Typically due to damaged wire strands
- Technical Order (TO) has limited instructions on dealing with wiring
 - Cannot deviate from TO
 - Need to have instruments approved and listed in TO
- Electricians want a piece of equipment the size of a multimeter with enhanced capabilities such as high sensitivity, TDR, toner probe and data collection
- Current phase inspection is primarily visual
 - Opportunity to introduce electrical integrity check on specific wire bundles



Wiring Integrity Study of Legacy Aircraft Results- Depot (2 locations)



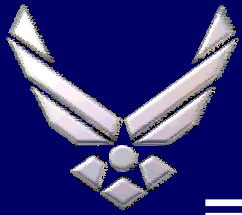
- Large/complex wire test systems used to primarily verify mods and repairs (may take several days)
 - Majority of wiring not tested during PDM(programmed depot maintenance)
 - Overall wiring in good condition- each aircraft type has several known problem areas
 - Failures due to wear and tear and handling during mods/ upgrades
 - Most wire problems are not documented in a recoverable database
- Depot process unique for each aircraft type
 - F-16 maintenance primarily a field activity
 - KC-135 has extensive PDM and major rewire effort
 - B-1B has PDM and large wire mod effort
- Wiring Troubleshooting primarily with a multi-meter
 - Aircraft BIT/ testers identify LRU failures
 - May replace several LRUs before wiring considered



Wiring Integrity Study of Legacy Aircraft-Findings



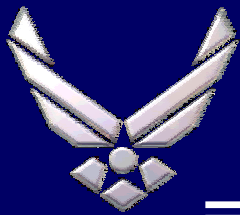
- Wiring failures may have a significant impact on maintenance costs
 - Maintenance tracking data bases not showing extent of problems
 - Primarily anecdotal evidence
 - Damage occurring during maintenance actions and exposure to moving parts and external environment
 - Material degradation only apparent in older insulation materials (20+ years)



Wiring Integrity Study of Legacy Aircraft-Findings



- Wiring failures found after an inability to resolve a system failure or during visual inspections
- Wiring problem areas
 - Fuel tank wiring
 - Wheel wells- anti-skid systems
 - Generator wiring
 - Wing flaps and leading edges
 - Pylon wiring
 - Circuit breaker panels
 - Control column wiring
 - Equipment rack wiring (wiring within one foot of connectors)
 - Wiring nexus points (wing root areas, under wings, cockpit)



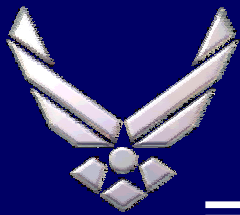
Wiring Areas of Interest



Leading Edge Wing Flap Harness

- Moving parts in combination with grease and extreme environmental conditions cause wiring problems
- Double-Back harness in leading edge has problems with bolts chafing the harness

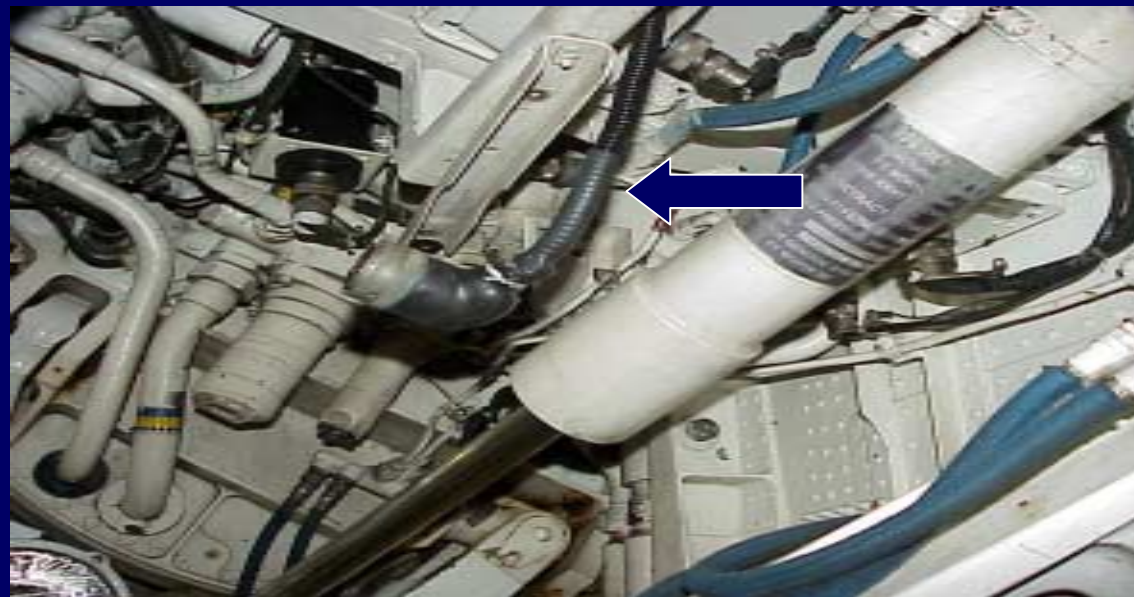


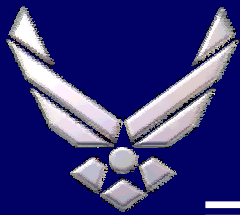


Wiring Areas of Interest

Wheel Wells

- Environmental exposure of connectors and wiring
- Wiring has exhibited damage from repeated flexing



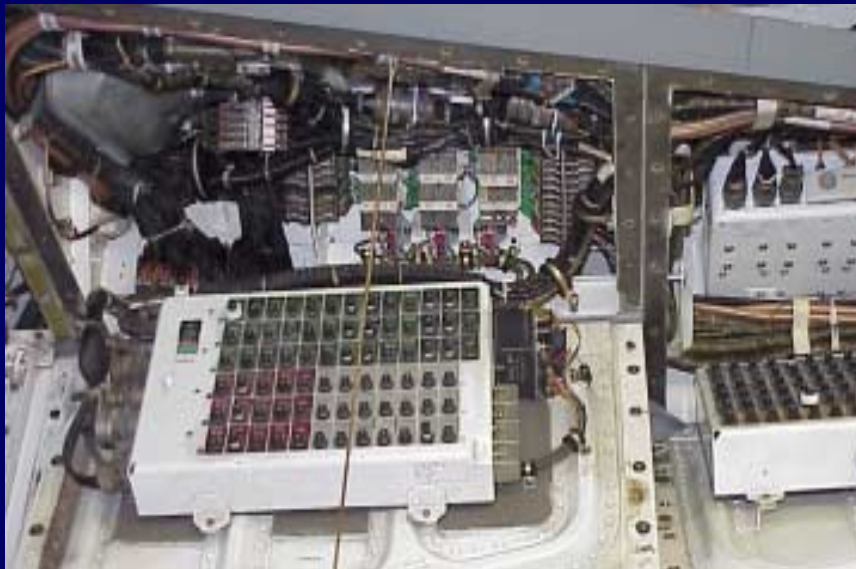


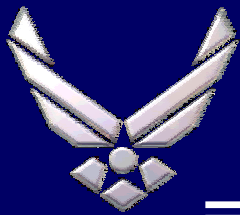
Wiring Areas of Interest



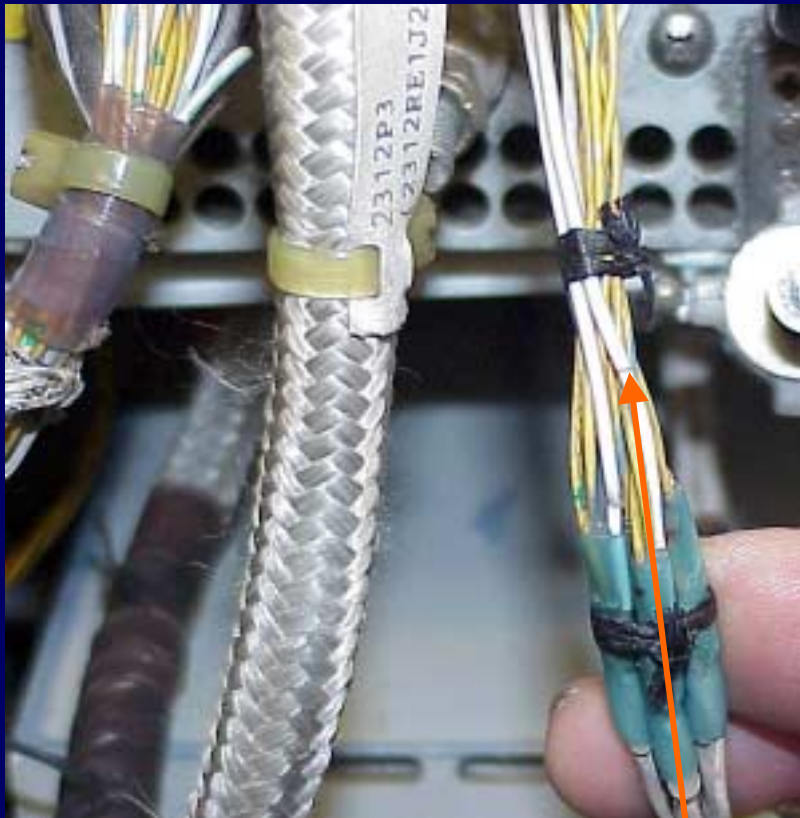
Circuit Breaker Panels

- Due to constant opening and closing of the panels, the wires can become damaged



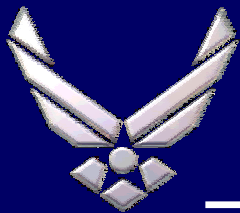


Wiring Areas of Interest

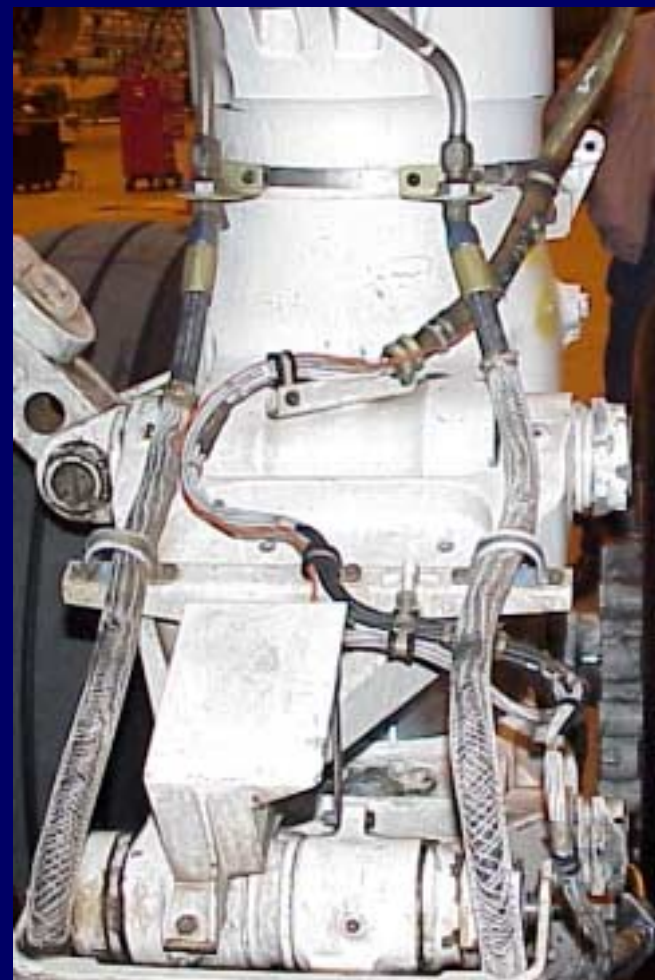


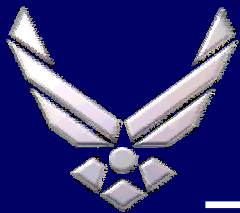
Avionics Wiring

Crack in
Wiring

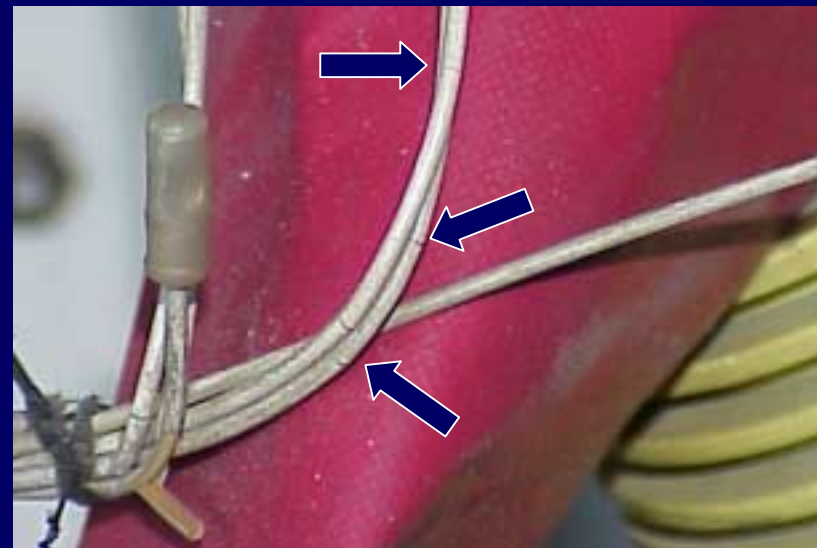


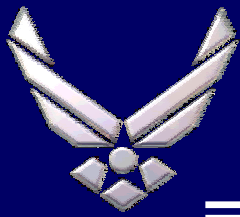
Wiring Areas of Interest





Wiring Areas of Interest





Wire Integrity System for Legacy Aircraft



Purpose:

Deploy a wire diagnostic and verification system

Proposed Effort

Sponsor: AF Aging Aircraft Program Office

Funding: FY01 FY02 FY 03
 2MY 2MY 1MY

Start Date: 31 Oct 2000

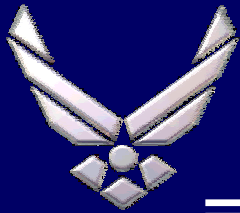
POC: Eddie White DSN 986-9162

Approach

- Transition system to depot and field use
- Provide electrical characterization of wiring
- Diagnostic and Predictive capability

Benefits: (Projected)

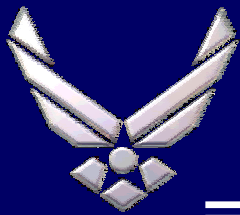
- Fielded system for identifying and locating intermittent wiring faults
- Reduction in maintenance time during troubleshooting and lowering of failures
- Application to multiple weapon systems



Wire Integrity System for Legacy Aircraft Program Outline

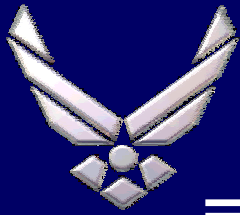


- Program Approach
 - Identify wiring issues (F-16 and others)
 - Develop tester requirements
 - Initiate program to enhance current wiring test systems
 - Program selected by AF Aging SPO for FY01
 - System will be optimized at AFRL
 - System will be deployed in field for evaluation
 - Hand-held and suite-case sized systems envisioned



Wire Integrity System for Legacy Aircraft System Concepts

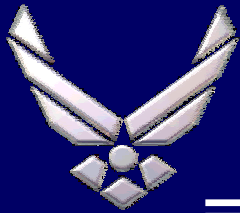




Wiring Test System Requirements



- Field level wiring test system requirements
 - Size and setup times
 - Identify most critical parameters to measure
 - Troubleshooting, verification, and integrity checking
- Integration into current test equipment and practices
 - Phase inspections
- Functional capability
 - Find “hard” shorts and opens (Now)
 - Physically locate damage sites (Maybe)
 - Locate intermittent and degraded interconnections (Maybe?)
 - Store results (Now)
 - Use data collected to enhance wire integrity (Maybe?)



Analysis of Wiring Maintenance Data



Purpose:

Analyze how the current maintenance data collection identifies wiring system failures

Proposed Effort

Sponsor: AF Aging Aircraft Program Office

Funding: FY00

Start Date: 1 Aug 00

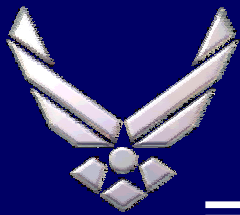
POC: Abigail Cooley DSN 986-9155

Approach

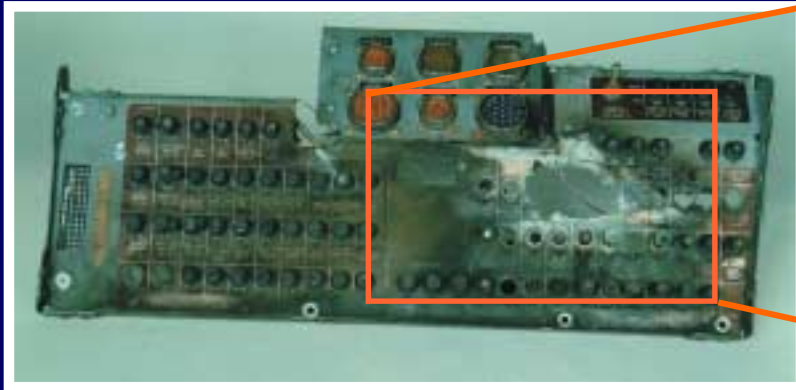
- Identify how wiring failures are coded
- Determine quantity and type of failures
- Identify organizations that could improve the data collection process

Benefits: (Projected)

- Documentation of wiring failures
- Improvement in data collection system
- Application to multiple weapon systems



In-Flight Electrical Fire Due to Circuit Breaker Aging Mechanism



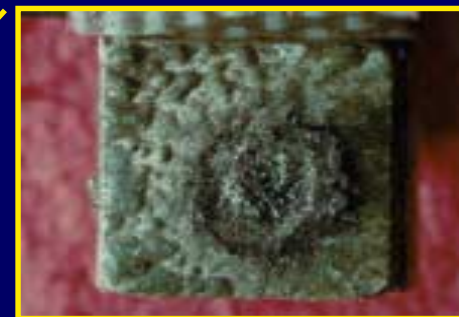
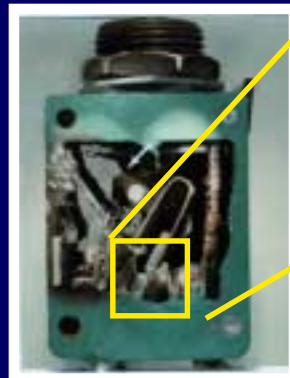
Circuit Breaker Panel



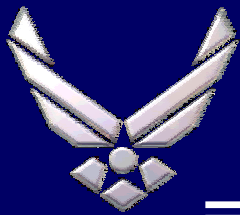
Close-up of Fire Damage



Failure Initiated by Over Heated CB



Aging of CB Contacts Caused Failure



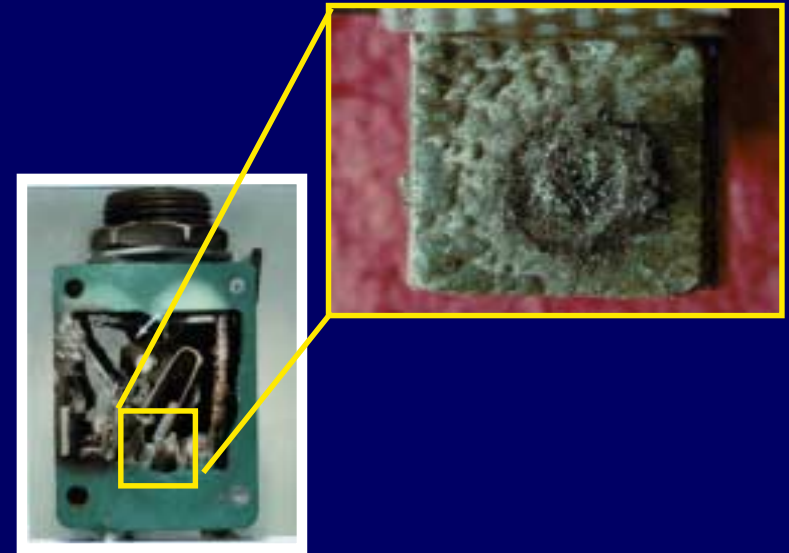
Aging Circuit Breaker Study

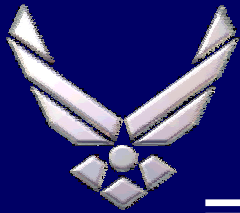


Problem:
Aircraft experiencing CB
related failures

AFRL/MLSA In-house program

- Six month study started 1 March 2000
- Characterizing CBs removed from aircraft
 - Identify failure mechanisms
 - Correlate failures to time, circuit application and environmental factors
- Premature tripping noted on 20A CBs
 - Materials related failure mechanism



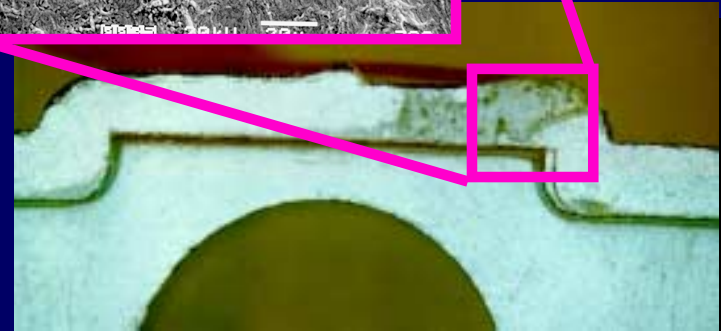
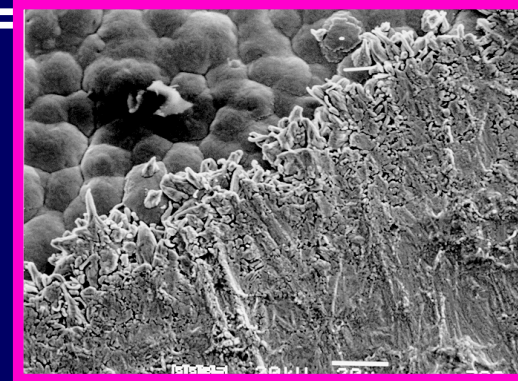


Aging Electrical Connectors



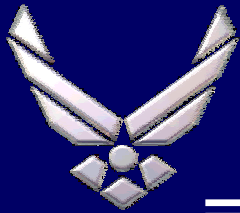
Problem:

- Ni/Cd Al connector corrosion issue
- Degraded connector electrical bonds can degrade EMI shielding
- Environmental initiative to reduce cadmium and nickel



Approach:

- AFRL/MLSA In-house program
- Six month effort
- New materials show significant bonding improvement
IVD aluminum, Titanium, stainless steel, Aluminum/Bronze



Conductive Polymer Replacement for Aerospace Wiring



Proposed Effort

Sponsor: AFRL/ML

Funding: FY00 FY01

6.2 2 MY

STTR \$250K \$250K

Start Date for 6.2 effort: Nov 01

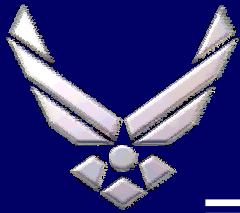
POC: Eddie White DSN 986-9155

Purpose: Develop a conductive polymer for signal applications

- Electrical characterize polymer
- Fabricate wire
- Conduct environmental tests
- Evaluate on aircraft

Benefits: (Projected)

- Reduced 50% weight reduction
- 200-300% strength increase
- Application to multiple weapon systems



Development Of Techniques For Managing Wiring Systems



Purpose:

Employ a systems approach that can effectively and safely manage electrical interconnection systems in legacy and new aerospace vehicles

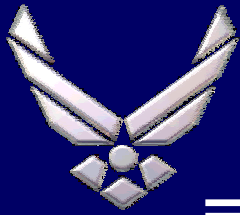
Funding: FY02 FY03 FY 04
AFRL/ML(DP)
FAA
6 MY 6 MY 6 MY
Start Date: 31 Oct 2001
POC: Joseph Kuzniar

Approach: Develop advanced management tools and processes for

- Inspection
- Maintenance
- Troubleshooting
- Repair of aircraft electrical interconnection systems

Benefits: (Projected)

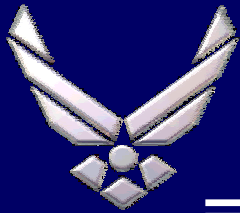
- Reduced wiring field failures
- Selection of most effective aging wiring tools for evaluation
- Identification of new research opportunities



AFRL Aging Wiring Interest Areas



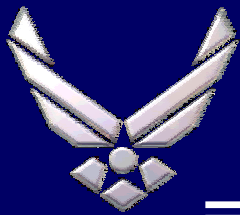
- Failure Characterization
 - Time dependent failure mechanisms
 - Degradation mechanisms- electrical effects
 - Defect sensitivity/sizes analysis
- Diagnostics/Detection
 - NDE techniques/test protocols
 - Prognostics
 - Sensors (MEMs)
- New Materials
 - Conductor (polymer replacement for copper)
 - Insulation (more robust with balanced properties)



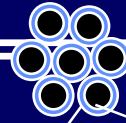
AFRL Aging Wiring Interest Areas (Con't)



- Interconnection Technologies
 - Circuit breakers (arc sensitive and MEMs)
 - Connectors (new materials)
- Maintenance (Managing aging wiring)
 - Tools for collecting wiring field data
 - Extended and predictable failure-free operating periods
 - Replacement/repair processes



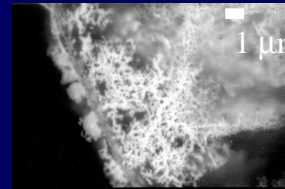
Managing Aging Wiring Systems



New Materials



Diagnostics and Inspection



Managing Aging Wiring Systems

TECHNOLOGY INTEGRATION



Failure Characterization



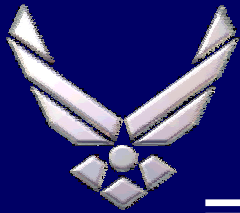
Interconnection Technologies

- Circuit Breakers
- Connectors



Maintenance Procedures





Summary



Wiring System Integrity Can Be Managed

- Emphasis on proper design, materials selection, installation, and maintenance practices
- Collection and analysis of maintenance data
- Understanding of failure mechanisms
- Use of surveillance programs
- Treating wiring as an interconnection system
- Use of proactive repair and replacement programs